Chapter 6: Waves

Lesson 6.1 Describing Waves

1 2 waves

2 As the amplitude increases, the amount of energy transferred by a wave increases.

3a $f = 1 / T = 1 / 0.1 = 10$ Hz

3b $f = 1 / T = 1 / 0.25 = 4$ Hz

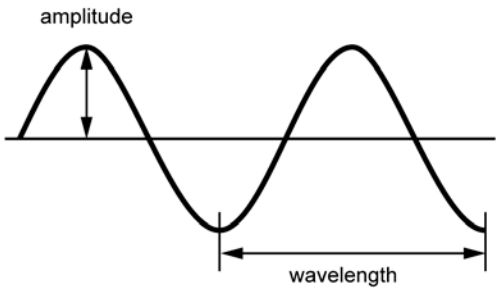
4 $v = f\lambda = 2$ Hz × 0.1 m = 0.2 m/s

5 The wavelength will halve (assuming the speed stays the same).

6 Since v = fλ then v is 6 times bigger.

Lesson 6.2 Transverse and longitudinal waves

1



2 Objects floating on water bob vertically up and down as waves pass along the water.

3 Alex is wrong because in a transverse wave, the vibrations are at right angles to the direction the wave is moving, so the water doesn't move along with the wave. The objects might be moving over the water because the wave has transferred energy to their kinetic energy store – but they are not being carried along with the water.

4 D (transverse)

5 You could lay a slinky spring next to a ruler on a bench. Set up a video camera to record the wave and set it recording before the wave is produced on the slinky. Produce a longitudinal wave on the slinky and then stop recording. Play back the wave in slow motion. Use the ruler to record the location of a link on the slinky before the wave is produced. Then observe the motion of that link as the wave passes and record the maximum distance it travels away from its original position. This maximum distance is the amplitude of the wave.

6 The sound wave shown by the blue graph has the highest frequency.

7 15 cm

8 The sound waves travel through the iron railing and also through the air. Sound travels faster through the iron railing so Ann hears the sound wave that has passed along the iron railing first and then she hears the sound wave that has passed through the air.

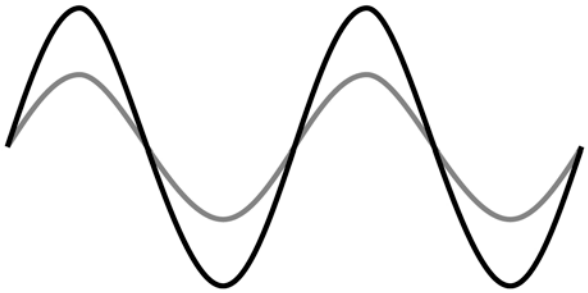
9 Speed of sound in air at 50 ^{0}C = 331 + (0.6 × 50) = 361 m/s.

$\lambda = v / f = 361 / 1000 = 0.361$ m.

Lesson 6.3 Key Concept: Transferring energy or information by waves

1 Sound travels much more slowly than light does.

2



3 If the amplitude of a sound wave increased, you would hear a louder sound.

4 Data is sent faster and over greater distances through fibre optic cables than through copper wires.

5 e.g. Some food absorbs microwaves

Ultraviolet light can be reflected by snow

X-rays can be reflected in x-ray telescopes

Gamma rays are absorbed by lead

6 The Sun is replenishing its energy from fusion reactions inside its core. (It is actually losing energy but this results in its mass decreasing rather than its temperature.)

Lesson 6.4 Measuring wave speeds

1 Time between claps is 23 / 50 = 0.46 s.

Speed = distance / time = 100 m / 0.46 s = 217 m/s.

2 e.g. the wind might be affecting the speed the sound goes; problems with clapping at the same time that you hear an echo; measuring errors in the distance and the time.

3a This is not an accurate method. It would be hard to judge exactly when the wave reached the other end of the swimming pool. There are also likely to be many other waves in the pool which would make the measurement confusing. Also there is only one measurement.

© HarperCollins*Publishers* Limited 2016

3b You could repeat the experiment several times and take an average. You could also video the wave from above and use software to play the video back in slow motion and to calculate the time it took the wave to travel the 25 m.

4 speed = distance / time = 20 / 10 = 2 m/s.

5a Distance = speed × time = 1500 × 0.1 = 150 m.

The sound has travelled to the fish and back again so the distance between the boat and the fish = 150 / 2 = 75 m.

5b The reflected pulse has come from lots of fish at different depths. So the time it takes for the wave to return becomes spread out.

6a Distance = 220 × 2 = 440 m

6b Time = distance / speed = 440 / 330 = 1.3 s.

7 If the pulse is spread out then the echoes will also be very spread out. This will make it difficult to measure an exact time between the pulse and the echo – so the distance calculation will have more uncertainty.

Lesson 6.5 Required Practical: Measuring the wavelength, frequency and speed of waves in a ripple tank and waves in a solid

1 It shakes the rod, which produces the ripples in the tank.

2a m or cm

2b Hz

3 You could use a transparent ruler taped onto the bottom of the tank of water. The shadow of the ruler can be used to measure the distance between the ripples on the viewing screen.

4 This makes the measurement more accurate.

5 She would divide the number of waves she counted by ten.

6 They could look at a single ripple and time how long it took to move a certain distance between to markers on the viewing screen.

7 They could use a strobe light to freeze the pattern. The frequency of the waves would equal the frequency of the strobe light. They could find the wavelength by measuring the distance between two ripples with a ruler.

8 If both methods give the same answer then it is likely that their conclusions are valid. If you only use one method you can't be sure that the measurement is correct as there is nothing to check it.

9 You can use a metre ruler by taping it to the bench.

10 You need to place your head directly above the ruler to measure the distances accurately which would be difficult to do perfectly. The pattern might not be stable, so that it is moving around slightly. The ruler might not be completely parallel to the string.

11 You could measure the speed for the different patterns that are formed. If all of the speeds are nearly the same you could be confident that your measurement accurately measured the true speed of the waves on the string.

Lesson 6.6 Reflection and refraction of waves

1 When light reflects you would see an image / reflection; when sound reflects you would hear an echo; when a water wave reflects you would see the wave moving back in the opposite direction. We are assuming that the surface that they are reflecting off is smooth.

2a The sound would disappear and you wouldn't hear it.

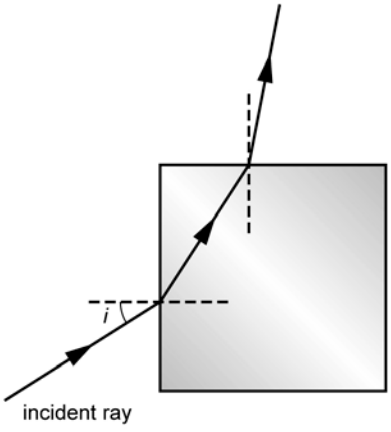
2b You would hear an echo but it would not be as loud as the original sound.

3 40^0. The ray diagram should look like figure 6.18.

4 The angle of incidence = $90^0 – 35^0 = 55^0$, so the angle of reflection is 55^0.

5 When light speeds up (e.g. when it passes out of a glass block into the air).

6



Lesson 6.7 Required Practical: Investigate the reflection of light by different types of surface and the refraction of light by different substances

1 e.g. unpolished shoes; rock; wood

2 A car driver might be dazzled if the light from their headlights is reflected from the bicycle in front of them straight back into their eyes.

3 They could use a ray box to produce the light ray, a mirror, a protractor to measure the angles, a

 © HarperCollins*Publishers* Limited 2016

piece of white paper, a pencil and a ruler. Place the mirror vertically on a piece of white paper and draw a line along its edge. Remove the mirror and draw in a normal line at 90^0 to the line that is already on the paper using the protractor and pencil. Replace the mirror and shine a ray of light from the ray box so that it hits the mirror at the normal line. Use the pencil and the ruler to draw lines along the incident ray and the reflected ray. Measure the angle of incidence and the angle of reflection between the rays and the normal line by using the protractor.

4 They should measure them from the normal line.

5 e.g. the mirror could move; the pencil lines could be too thick to measure the angles from. Fix the mirror in place with tape; use a sharp pencil; take repeat readings and find a mean value.

6 You could plot a graph with the angle of incidence on the x-axis and the angle of reflection on the y-axis. The shape of the line of best fit shows you the relationship between the angles.

7 No – the angle of reflection always equals the angle of incidence but in diffuse reflections the normal lines are in many different directions because the surface is rough.

8a The angle of refraction is smaller than the angle of incidence – this happens when the light slows down.

8b The angle of refraction is larger than the angle of incidence – the light has sped up.

9 It should leave the block in the same direction as it entered.

10 No – because at some angles the light would come out of the right hand side of the block rather than the bottom edge.

11 They should put the water into a transparent container with very thin walls. The container should be the same shape as the glass block. The walls should be thin to minimise the effect of refraction in the container so that nearly all the measured refraction is due to the water. They should then carry out the same procedure as they did with the glass block.

Lesson 6.8 Sound waves

1a No

1b Yes

2 $f = v / \lambda$ so if the wavelength increases, the frequency decreases (the speed stays the same). This means that the sound will be lower in pitch.

3 16 cm

4 The air particles vibrate to the left and right about a fixed position as the longitudinal wave passes through them.

5 The vibrating air particles in the ear canal transfer energy to the energy store of the ear drum. This makes the ear drum vibrate. In turn, the ear drum makes the ossicles vibrate which make the fluid in the inner ear vibrate. The inner ear transfers energy from the energy store of the fluid in the inner ear into electrical impulses in the nerves.

6 This would make the coil vibrate with a large amplitude and a high frequency.

Lesson 6.9 Exploring ultrasound

1 It has a frequency that is too high for humans to hear.

2 Sound has a longer wavelength than ultrasound and this means that it can't be focused into a narrow beam. This would blur the image.

3 X-rays are particularly dangerous to bodies that are growing rapidly (such as a developing baby or a young child). So using ultrasound is much safer.

4 e.g. checking the health of unborn babies; checking that materials used in aircraft don't have any cracks in them.

5 An ultrasound image can detect cracks in pipes so this will determine whether there is a leak.

6 If the speed changes by a large amount then most of the ultrasound is reflected. This might be a problem because if most of the ultrasound is reflected then the ultrasound that can pass to deeper structures in the body becomes very weak and these structures might not be able to be imaged.

7 To prevent too much reflection so most of the ultrasound passes into the body.

8 A short pulse of ultrasound waves is transmitted into the body. When the pulse hits a boundary (e.g. between one tissue and another tissue) some of it reflects back and some of it continues onwards. By measuring the reflected pulses, a computer can form an image of the structures inside the body.

9 The second pulse has travelled further than the first pulse. The extra distance it goes is twice the size of the head (because it passes through the head and reflects back again).

Let the size of the head = d

Distance = speed × time

$2d = 1500 \times 140 \times 10^{-6} = 0.21$ m

So $d = 0.21 / 2 = 0.105$ m or 10.5 cm

© HarperCollins*Publishers* Limited 2016

10 Lungs are full of air. Ultrasound travels at a very different speed in air than in body tissue so most of the ultrasound would reflect back from the lungs. Therefore, any pulses passing to the other side of the lungs would be far too weak to be used to form an image.

Lesson 6.10 Seismic waves

1 Gravity

2 The base of the seismometer needs to move around with the rock while the weight remains still.

3a Longitudinal

3b Transverse

4 A P wave travels faster than an S wave.

5 The density of the Earth gets larger the further in you go towards to core and so the speed of the waves increases. As this is a gradual change of density then the speed also gradually changes. The waves gradually refract and so they curve rather than change direction suddenly.

Lesson 6.11 The electromagnetic spectrum

1 A transverse wave vibrates at right angles to the direction that it travels and a longitudinal wave vibrates along the same direction that it travels.

2 They don't need a material to carry them; they can travel in a vacuum.

3 They are all transverse waves and they all travel at the same speed in a vacuum.

4 Gamma rays

5 $f = v / \lambda = 3.0 \times 10^8 / 3.5 \times 10^{-7} = 8.6 \times 10^{14}$ Hz

6 $f = v / \lambda = 3.0 \times 10^8 / 0.2 = 1\,500\,000\,000$ Hz $= 1.5 \times 10^9$ Hz

7 Ultraviolet waves have a higher frequency than radio waves. Therefore, they can transfer more energy. This increases their ability to do harm.

8 The food in the oven warms up, which means that the waves have transferred energy from the oven to the food.

9 The waves spread out so the energy that they carry becomes diluted. This means that the signal becomes weaker the further away you are from a phone mast.

Lesson 6.12 Reflection, refraction and wave fronts

1 Aluminium foil is shiny so it is a good reflector of infrared radiation. Therefore, the heat is reflected back into the room rather than absorbed by the walls. This reduces heat transferring through the walls and so reduces the heating bills.

2 e.g. a thermos flask, white buildings in hot countries

3 $\lambda = v / f = 3.0 \times 10^8 / 10 \times 10^6 = 30$ m

4 $f = v / \lambda = 3.0 \times 10^8 / 100 = 3.0 \times 10^6$ Hz $= 3.0$ MHz

5 Under the right conditions, radio waves can reflect off the atmosphere. This enables them to reach places that are out of line of sight due to the curvature of the Earth.

6a The wavefronts get closer together and they change direction.

6b They travel faster in deeper water. The diagram shows that they slow down when they enter shallow water because they become closer together (like cars do in a traffic jam).

Lesson 6.13 Gamma rays and X-rays

1 It is long enough to be useful but not too long so that the patient is exposed where there are no more benefits.

2 They should be gamma emitters; they should not be dangerously toxic.

3 Usually radiotherapy needs X-rays which transfer a higher energy than the X-rays used for imaging. This means that X-rays used for radiotherapy will tend to have shorter wavelengths.

4 Gamma rays can pass straight through bone and tissue so there wouldn't be enough contrast in the image to enable any diagnosis to take place.

5 Similarities: they are both electromagnetic wave.

Differences: Gamma rays tend to have a higher frequency than X-rays (although there is some overlap); gamma rays come from the nucleus of an atom whereas X-rays are produced by the elctrons.

6 Gamma rays come from a radioisotope which doesn't need electricity to work. X-rays are produced by accelerating electrons so they collide with a target with high energy. You need an electricity supply in order to accelerate the electrons.

7 They are dangerous and can give you radiation sickness / cancer.

8 The X-ray image is different if there is a fault in a weld so an expert can detect the fault.

9 The chest X-ray has a very small dose compared to what an average person would receive anyway so this procedure is relatively safe and the benefits for most people would easily outweigh the risks. The CT scan has a much bigger dose but this is still below what an average person would receive from natural sources. So if you only have one CT in a year then it is relatively safe although the

 © HarperCollins*Publishers* Limited 2016

doctors need to decide whether the risk is worth it and CT scan will help them to make the patient better.

Lesson 6.14 Ultraviolet and infrared radiation

1 e.g. security marking; tanning; producing vitamin D

2 You can use an invisible ink that glows when ultraviolet light is shone on it.

3 So they can check the bank notes to see if they are genuine.

4 Ultraviolet lights often do have a purple colour but this is due to the visible light they produce in addition to the ultraviolet. This is a safety measure to show the user that they are switched on. Ultraviolet light is invisible to our eyes so it has no colour.

5 Small doses help your body to make vitamin D. Large doses can cause sunburn or skin cancer.

6 Snow reflects ultraviolet light so skiers will be exposed to more ultraviolet than people on the beach if the sunlight is the same in both situations.

7 Infrared radiation can't pass through the chicken. You need to wait for the inside of the chicken to be heated by other processes.

8 Conduction.

9 e.g. they can detect the presence of a warm body and set the alarm off; they can be used with a beam of infrared and set the alarm off if the beam is blocked by something going past.

10 Infrared radiation reflects off surfaces, so the remote can point towards a surface and the infrared beam can reflect off this towards the TV.

Lesson 6.15 Required Practical: Investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface

1 The experiment shows how quickly a surface can absorb infrared radiation.

2 The stopper connected to the blackened metal plate should drop first. This is because black surfaces absorb infrared more effectively than shiny surfaces.

3 The thickness of the plates should be the same, the mass of the stoppers and the amount of wax used to stick them should be the same, the heater needs to give the same heat transfer in both directions and the plates need to be placed the same distance either side of the heater.

4 This ensures that the temperature of each surface is the same.

5 To make it a fair test and ensure that the effect of the area on the infrared radiation is kept the same.

6 The infrared detector needs to be placed the same distance from each of the sides of the container.

7 The blackened bulb will absorb the infrared effectively and so the thermometer can measure the amount of infrared being produced.

8 The infrared sensor.

9a A firefighter's suit needs to be white or shiny.

9b Solar panels needs to be matt black.

10a It needs to be shiny (so that it doesn't emit much infrared radiation).

10b They need to be matt black (so they emit lots of infrared radiation).

11 Although they are emitting different intensities of infrared light, the sides of the cube are all at the same temperature. This is because of conduction of heat through the walls from the water. Therefore, the thermometer would give the same reading on all of the sides.

Lesson 6.16 Microwaves

1 Mobile phones / Satellite communication / cooking

2 This is quite a long wavelength in the microwave region. Therefore, these microwaves have low energy and are likely to be used for communication.

3 Microwaves only cook water or fat molecules and they penetrate about 1cm beneath the surface of the food. Conventional ovens use infrared to cook food. Infrared red only reaches the outer surface of the food but it does cook all materials. Both processes rely on conduction for the remainder of the food to cook.

4 It is quicker because the microwaves penetrate into the food. Food is cooked more evenly because the microwaves heat up the food from the inside rather than just at the surface.

5 Usually bread is cooked using infrared. This makes the outside of the toast crispy and the inside moist. Making toast in a microwave oven would have the opposite effect. The inside would be baked hard (or burnt) and the outside will still be soft bread.

6 Distance microwave travels = speed × time = $3.0 \times 10^8 \times 64 \times 10^{-6}$ = 19 200 m. The microwave travels to the target and back so the target is 19 200 / 2 = 9 600 m away.

7 The signal gets weaker the further it goes so the equipment won't be sensitive enough. Also there are more reflections from other objects which confuse the signal, the further away the target

© HarperCollins*Publishers* Limited 2016

Lesson 6.17 Radio and microwave communication

1 Radio waves travel very fast (the speed of light) which means that communication can be very fast. Radio waves can travel large distances and they can pass through most walls.

2 $f = v / \lambda = 3.0 \times 10^8 / 100 = 3.0 \times 10^6$ Hz = 3.0 MHz.

3 A radio receiver has a wire or a coil. Radio waves induce oscillations in the wire or coil which results in a changing current. This current is the radio signal that the receiver picks up and can be turned into sound.

4 These radios use the energy transmitted by the radio waves for their power.

5 Microwaves don't pass through the walls of houses very effectively.

6 Buildings absorb microwave signals so you need lots of aerials for the signals to make sure that users can pick up a signal wherever they are.

7 They refract in the ionosphere and return to Earth.

8 Waves with this frequency don't return to Earth but are transmitted into space.

Lesson 6.18 Colour

1 No colours are reflected by a black object.

2 All the colours apart from yellow.

3 The colour of an object is the colour of light that it reflects.

4 All of the colours apart from blue.

5a red

5b black

5c black

5d black

6a black

6b green

6c black

6d green

7 A grey colour is the same as white only darker. Therefore, a grey object will partially absorb all the colours and partially reflect all of them.

Lesson 6.19 Lenses

1a It is the place where rays that are parallel to the axis meet once they have passed through the lens.

1b Yes, for example parallel rays that enter the lens at an angle to the principal axis will be focused onto another point.

2 The principal axis.

3 To reduce the focal length you would have to bend the rays more so they were focused closer to it. Therefore, the lens needs to have a fatter shape.

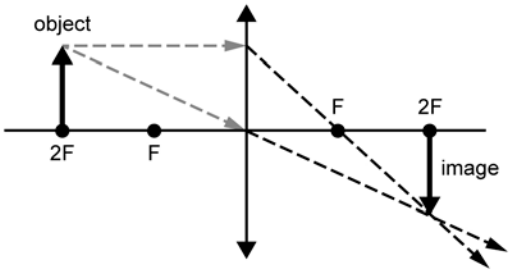
4 The light bends towards to the normal when it enters the lens and away from the normal after it leaves the lens. Due to the shape of the surface of the lens – this means that the light diverges.

5 If you draw rays from a point on an object near a lens, the rays that can enter the lens will spread apart from each other (diverge) quite steeply. Moving the object further away, the rays that can enter the lens will still be diverging but not as steeply – so they are more parallel to each other. The further away you move the object, the more parallel the rays get.

6 You can consider the centre of a thin lens to be the same shape as the middle of a rectangular block. This displaces the ray sideways but it still continues in the same direction (see section 6.6). If the lens is thin then the displacement is very small and so it looks like the ray does not refract at all.

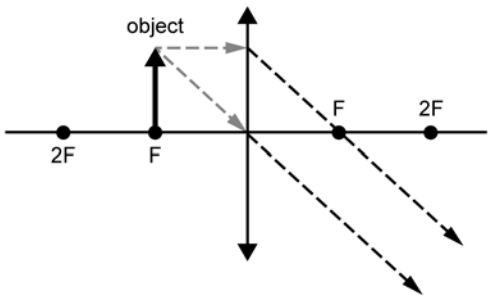
Lesson 6.20 Images and magnification

1



The image is inverted, it is real and it is the same size as the object.

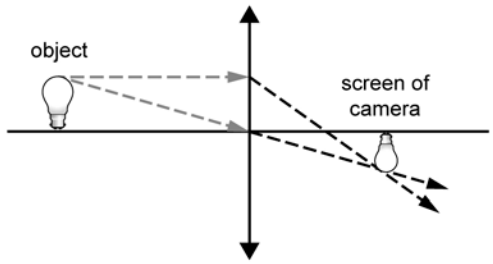
2



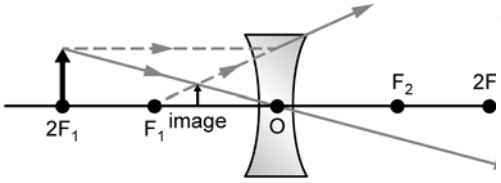
© HarperCollins*Publishers* Limited 2016

The image can't be formed because the rays entering the eye are parallel to each other. (It is also correct to say the image is virtual, an infinite size, the right way up and an infinite distance away)

3



4



The image is upright, virtual and smaller than the object.

5 1.2 cm = 12 mm. Magnification = 12 / 1.6 = 7.5

6 1.76 m = 176 cm. Magnification = 1.9 / 176 = 0.011 (to 2 significant figures)

7 A ray diagram drawn to scale will produce an image that is 2cm high and is 6cm to the right of the lens. Therefore, the magnification = 2 cm / 1 cm = 2.

Lesson 6.21 Emission and absorption of infrared radiation

1 The surface of the drink. It is the hottest part of the picture.

2 They also have a temperature (above absolute zero).

3 The shiny white side.

4 Shiny copper pipes are poor absorbers of infrared radiation. Painting them black makes them absorb the infrared more effectively so the water is heated more quickly.

5 It would be glowing white hot at a higher intensity than when it was at 7200 ^{0}C. It would also be producing electromagnetic radiation of a much shorter wavelength but this would be invisible to the eyes.

6 The white object would be the same colour as the black object in question 5 only much dimmer because it wouldn't be as effective at emitting radiation.

Lesson 6.22 Temperature of the Earth

1 The temperature is increasing.

2 White objects are poor absorbers and emitters of radiation. Therefore, the white objects warm up or cool down more slowly than black objects do.

3 It is at a temperature above absolute zero.

4 The mean temperature of the Earth is reached when the amount of infrared radiation it absorbs balances the infrared radiation it emits. Therefore, the mean temperature of the Earth depends on the activity of the Sun and the state of the atmosphere.

5a absorption: how reflective the Earth is – e.g. icy surfaces don't absorb infrared radiation very effectively

reflection: again, icy surfaces reflect infrared radiation more than other surfaces; cloud cover also reflects infrared radiation from the Sun and also from the ground

emission: this depends on the temperature of the Earth and the nature of the gases in the atmosphere which might absorb the radiation on its way back into space.

5b absorption: Humans add gases into the atmosphere which absorb the infrared radiation

reflection: Humans change the surface of the Earth (by building things)

emission: emission is changed due to human activities which affect absorption and reflection

6 Human activities have led to gases being put into the atmosphere which absorb the infrared radiation emitted from the surface of the Earth and prevent them from reaching space.

7 This could decrease the temperature of the Earth because the particles prevent the infrared radiation of the Sun from reaching the surface of the Earth. (This is a larger effect than the greenhouse effect that they might produce.)

8 The temperature of the Earth depends on many factors such as the output of the Sun, the varying weather patterns, oceanic currents etc. Even if there is a correlation between carbon dioxide levels going up and temperature going up, this does not necessarily mean that one of them causes the other. Also the temperatures change all the time over every part of the world and it is difficult to measure the average temperature change to a high degree of accuracy. So the

© HarperCollins*Publishers* Limited 2016

increase in temperature could be a random short term effect.

Lesson 6.23 Maths Skills: Using and rearranging equations

1a $T = 1 / 100 = 0.01$ s

1b $T = 1 / 1000 = 0.001$ s

1c $T = 1 / 15\,000 = 0.000067$ s $= 6.7 \times 10^{-5}$ s

2a $f = 1 / 5 = 0.2$ Hz

2b $f = 1 / 10 = 0.1$ Hz

2c $f = 1 / 150 = 0.0067$ Hz $= 6.7 \times 10^{-3}$ Hz

3a $v = f\lambda = 100 \times 2 = 200$ m/s

3b $v = 100 \times 2 = 200$ cm/s $= 2$ m/s

3c $v = 100 \times 2 = 200$ mm/s $= 0.2$ m/s

4 $f = v/\lambda$

5a $f = 25 / 0.5 = 50$ Hz

5b $f = 250 / 0.05 = 5000$ Hz

5c $f = 2500 / 0.005 = 500\,000$ Hz $= 500$ kHz

6a $\lambda = v / f$

6b $\lambda = 330 / 500 = 0.66$ m

7 Speed of red light = distance / time $= 3.0 / 1.0 \times 10^{-8} = 3.0 \times 10^{8}$ m/s.

$f = v/\lambda = 3.0 \times 10^{8} / 6.5 \times 10^{-7} = 4.6 \times 10^{14}$ Hz.

8 Frequency of sound wave in air $= v / \lambda = 330 / 0.25 = 1320$ Hz

In titanium, $\lambda = v / f = 6100 / 1320 = 4.6$ m (to 2 significant figures).

End of Chapter Questions

1 a) Sound wave [1 mark]

2 a convex lens [1 mark]

3 c) hertz [1 mark]

4 It is the maximum distance [1 mark] that a point moves from its undisturbed position [1 mark]

5 Gamma rays [1 mark]

6 $T = 1 / 4 = 0.25$ s [1 mark]

7 A radio wave [1 mark]

8 This is called diffuse reflection [1 mark]. The light has reflected in all directions [1 mark].

9 A = infrared and B = X-rays [1 mark for both correct]

10 Microwaves and infrared [1 mark]

11a Cooking and communication [1 mark]

11b Killing cancer cells and being used in a tracer [1 mark]

12 Magnification = image height / object height [1 mark] $= 2.5 / 7.5 = 1/3$ (or 0.33) [1 mark]

13 $v = f\lambda$ [1 mark] $= 2 \times 8 = 16$ cm/s (or 0.16 m/s) [1 mark]

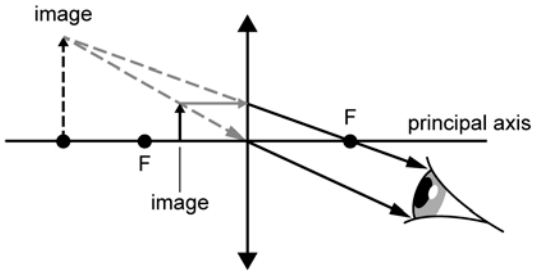
14 White is a poor absorber infrared radiation [1 mark] so the houses do not heat up as quickly by absorbing infrared radiation from the Sun [1mark].

15 Because its frequency is higher than 20 000 Hz which is the highest frequency humans can hear [1 mark].

16 Any colours apart from white and blue. [1mark]

17 White surface are both poor emitters and poor absorbers of radiation [1 mark]. Therefore, in hot countries the house remains cool as it absorbs infrared radiation slowly and in cold countries the house remains warm as it only emits infrared radiation slowly [1 mark].

18a



[1 mark for both of the rays drawn correctly, 1 mark for the correct location of the image.]

18b The image is virtual [1 mark], larger than the object [1 mark] (and the right way up).

18c The long sighted person looks at objects that are closer to the lens than one focal length [1 mark]. This makes the image further away and larger which both help the long sighted person to see the object clearly [1 mark].

19 As the ship is moving along the sea bed gradually becomes deeper, then stays at a constant depth and then gradually gets shallower [1 mark]. The anomalous result could be from a fish swimming underneath the ship but close to the surface.

20 Time between the pulses = 0.0600 – 0.0500 = 0.0100 ms

Distance travelled in this time = speed × time = 4000 m/s × 0.0100 × 10^{-3} s = 0.0400 m [1 mark]

© HarperCollins*Publishers* Limited 2016

This is the distance that the ultrasound travelled from the front of the stone to the back of the stone and then from the back of the stone to the front again.

So the thickness of the stone = 0.04 / 2 = 0.0200 m [1 mark].

21 Level 3: A detailed account of the absorption, emission and reflection of radiation that is taking place in the diagram. Observations are clearly linked to the diagram and the role of both radiation absorbed from the Sun and radiation emitted from the Earth are explored. The net transfer of energy from the Sun to the Earth due to the role of the greenhouse gases in the atmosphere is explained clearly. (5-6 marks)

Level 2: The absorption, emission and reflection of radiation are discussed but this is not completely clear or detailed and only loosely linked to the diagram. An attempt is made to explain the role of greenhouse gases in global warming and there is some relevant physics present. (3-4 marks)

Level 1: Some ideas about the absorption, emission and reflection of radiation are outlined. (1-2 marks)

Indicative content

Incoming radiation from the Sun

- The Earth is receiving 342 W/m^2 of radiation from the Sun.
- About a third of this (102 W/m^2) is reflected straight back into space.
- About two thirds is (240 W/m^2) is absorbed by the Earth and acts to warm the Earth up.

Outgoing radiation from the Earth

- The Earth re-radiates the energy it has received from the Sun.
- Because the Earth is cooler than the Sun, the wavelength of this radiation is longer than the radiation from the Sun.
- Some radiation transfers straight into space.
- Some radiation is absorbed by the clouds/atmosphere, which re-emits the radiation in all directions.

Global Warming

- Because the atmosphere absorbs some of the Earth's radiation and emits it back down to the surface then not all of it radiates back into space.
- If the intensity of radiation returning to space is less than 240 W/m^2 then the Earth will absorb more energy than it transmits and will warm up.

Greenhouse gas

- Greenhouse gases increase the atmosphere's ability to absorb radiation from the Earth's surface – reducing the amount returning to space.
- Greenhouse gases do not absorb the radiation from the Sun as effectively as they absorb radiation from the Earth (due to the different wavelength) so the radiation the Earth receives from the Sun is still around 342 W/m^2.
- Therefore, the larger the concentration of the greenhouse gas, the smaller the proportion of the energy from the Sun which is radiated back into space.

So a larger concentration of a greenhouse gas will warm the Earth up more.

© HarperCollins*Publishers* Limited 2016